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## SPECIFICATION

A Gas Supply Facility to a Chamber and a Method for an Internal

Pressure Control of the Chamber for which the Facility is Employed

### Field of the Invention

[0001] The present invention is concerned with a facility for gas supply to a chamber utilized with semiconductor manufacturing facilities and the like, and a method for an internal pressure control of the chamber for which the facilities is employed.

### Background of the Invention

[0002] In recent years, gas supply facilities equipped with a so-called pressure type flow controller to be used for a gas supply facility to a process chamber have been widely used.

[0003] An example is illustrated in Figure 8. It is so constituted that pressure type flow controllers C1, C2 and C3 and fluids switching valves D1, D2 and D3 are provided with a gas supply facility, and switching of fluids supplied to a process chamber E and flow rate adjustments are automatically performed by signals from a controller B (TOKU-KAI-HEI No.11-212653 and others).

[0004] It is so constituted that, with the aforementioned pressure type flow controllers C1, C2 and C3, a flow quantity  $Q_c$  passing through an orifice is computed with a formula  $Q_c = K P_1$  by a computation device M by maintaining fluids pass through an orifice Ka under critical conditions ( $P_1/P_2$  larger than approx. 2) as illustrated in Figure 9, to open or close a control valve V (to regulate pressure P1 on the upstream side of an orifice) so that the difference  $Q_y$

[0005] with a set flow rate  $Q_s$  is made to be zero. Here, A/D designates a signal converter, and AP an amplifier (TOKU-KAI-HEI No.8-338564).

[0006] As shown in Figure 10, the internal pressure of the aforementioned process chamber E is maintained at a set value (10 - 10 Torr) by continuously operating vacuum pumps VP1 and VP2 through an evacuation line Ex having a comparatively large bore equipped with an automatic pressure controller APC and a conductance valve CV.

[0007] A combination of a primary vacuum pump (a high vacuum pump) VP1 such as a turbo molecular pump and the like and a secondly vacuum pump (a low vacuum pump) VP2 such as a scroll pump and the like is widely employed for the aforementioned vacuum pump while an exhaust system for which one pump having a large exhaust volume and a large compression ratio is used has a disadvantage in manufacturing costs and the like, so it is not popular.

[0008] A fluids supply facility to a chamber shown in Figure 8 has characteristics that pressure type flow controllers C1 - Cn used for the facility are not influenced by internal pressure changes on the side of the chamber E. Therefore, the facility which allows comparatively stable control on the flow rate of the supply gas achieves an excellent, practical effect even with internal pressure changes of the chamber as long as critical conditions are maintained.

[0009] However, there are found various difficulties with this type of fluids supply facilities. Among these difficulties, to improve flow rate control accuracy in a small flow quantity range is the one which is needed to be solved urgently.

[0010] For example, on the assumption that flow rate control accuracy of a pressure type flow controller which rated flow rate is 1SLM (the gas flow rate converted to a standard state) is set at 1%F.S. in a setting of less than 10%, there may be a possibility that an error of a maximum of 1SCCM with the control flow rate value of a set 1%. Accordingly, when the control flow rate becomes less than 10% of the rated flow rate

(for example, less than 10-100SCCM), influence of the error of the aforementioned 1SCCM cannot be ignored. As a result, an accurate flow rate control cannot be expected in a small flow quantity range of less than 100SCCM.

[0011] With the process chamber E in the afore-shown Figure 10, continuous operation of a primary pump VP1 and the like such as a turbo molecular pump and the like having a high compression ratio and a large exhaust volume is needed.

[0012] Furthermore, to reduce loads of the primary vacuum pump VP1 and the secondary vacuum pump VP2, it becomes necessary that a diameter of the pipe for an evacuation line Ex needs to be relatively large. In addition, a conductance valve CV, an automatic pressure controller APC and the like are required. Accordingly, equipment costs of a vacuum chamber E go high, and the reduction of the costs becomes difficult to be achieved.

[0013] Patent Literature: TOKU-KAI-HEI No.11-212653

[0014] Patent Literature: TOKU-KAI-HEI No.8-335846

#### Disclosure of the Invention

##### Object of the Invention

[0015] The present invention aims to solve the aforementioned problems related to a gas supply facility to a vacuum chamber equipped with a conventional pressure type flow controller and an evacuation system of the aforementioned vacuum chamber, namely, (1) difficulty in performing accurate flow control with a gas supply facility in a flow rate range of less than 1% due to the reason that flow rate control accuracy is deteriorated in a small flow quantity range, thus a flow rate control range being limited to the range of approximately 1-100%, and (2) difficulty in downsizing a facility, and reducing facility and operation costs with the exhaust system of a vacuum chamber. It

is a primary object of the present invention to provide a fluids supply facility and a method for internal pressure control of the vacuum chamber for which the said fluids supply facility is employed, to make it possible to perform accurate flow rate control regardless of internal pressure changes of a vacuum chamber over the wide range of the required maximum set flow rate of 0.1% - 100%.

#### Means to Achieve the Object

[0016] The present invention as claimed in Claim 1 is fundamentally so constituted that it comprises a plurality of pressure type flow controllers connected in parallel and a controller to control the operation of an aforementioned plurality of pressure type flow controllers, and, with a gas supply facility to supply a gas while controlling the flow rate of the desired gas to a chamber exhausted by a vacuum pump, the aforementioned pressure type flow controller comprises an orifice, a pressure detector provided on the upstream side of the orifice, a control valve provided on the upstream side of the pressure detector, and a computation control part whereby a gas flow rate  $Q_c$  passing through the orifice is computed with pressure  $P_1$  detected by the pressure detector using a formula  $Q_c = K P_1$  (where  $K$  is a constant) and a difference  $Q_y$  with the set flow rate  $Q_s$  is outputted to a control valve as a driving signal, and makes it to be used under a condition that the ratio  $P_1/P_2$  on the pressure  $P_1$  on the upstream side of the orifice and the pressure  $P_2$  on the downstream side is maintained more than approximately two times, and also allows accurate flow control over the wide flow rate range by making one of the aforementioned pressure type flow controllers to be a controller to control the gas flow rate range up to 10% of the maximum flow rate to be supplied to a chamber, while the remaining pressure type flow controllers to be controllers to control the rest of the gas flow rate range.

[0017] The present invention as claimed in Claim 2 according to Claim 1 is so made that two pressure type flow controllers are connected in parallel, and one is made to be a controller for a small flow quantity range, while the other is made to be a pressure type flow controller for a large flow quantity range.

[0018] The present invention as claimed in Claim 3 according to Claim 1 is so made that two pressure type flow controllers are connected in parallel, and the flow rate range of the pressure type flow controller for a small flow quantity is made to be 0.1-10% of the maximum flow rate, while the flow rate range of the other pressure type flow controller for a large flow quantity is made to be 10-100% of the maximum flow rate.

[0019] The present invention as claimed in Claim 4 according to Claim 1 is so constituted that a plurality of pressure type flow controller is made to be operated starting with a pressure type flow controller for a smaller flow quantity range to one for a larger flow quantity in turn by means of control signals remitted from a signal conversion part in the controller.

[0020] The present invention as claimed in Claim 5 according to Claim 1 is so constituted that a rising rate setting mechanism of control signals to be remitted to the pressure type flow controllers allotted for all the flow rate ranges is provided with the flow controllers, and the said pressure type flow controllers supply the set flow rate of gas after a specified lapse of time following the remittance of the aforementioned control signals.

[0021] The present invention as claimed in Claim 6 is fundamentally so constituted that, with a chamber whereto gas is supplied from a gas supply facility equipped with a pressure type flow controller, and wherewith the inside is continuously decompressed by a vacuum pump through an exhaust line equipped with a conductance valve, firstly

the aforementioned vacuum pump is continuously operated to supply a desired gas from a gas supply facility, relationships between a gas supply flow rate and an internal pressure of a chamber are determined at both the maximum degree and minimum degree of opening of the aforementioned conductance valve respectively, and next, a control range is determined for a gas supply flow rate to a chamber equipped with the aforementioned exhaust system and the control range of the internal pressure of the chamber out of relationships of the internal pressure of the chamber and the gas supply rates, and a gas flow rate is regulated while the gas being supplied from the aforementioned gas supply facility to the gas supply flow rate corresponding to the internal pressure of the chamber to be set determined out of the line to show relationships between the said gas supply flow rate and the internal pressure of the chamber is maintained at the desired set pressure.

[0022] The present invention as claimed in Claim 7 according to Claim 6 is so made that the internal pressure of a chamber is maintained at the set pressure by regulating both opening of a conductance valve of the exhaust system and the supply flow rate of the gas from a gas supply facility.

[0023] The present invention as claimed in Claim 8 is so made that a gas supply facility is made to be a gas supply facility as claimed in Claim 1.

#### Effects of the Invention

[0024] With a gas supply facility to a chamber according to the present invention, the required flow rate range is divided into a plural number of flow rate ranges, and a small flow quantity range of less than 10% of the maximum flow rate is controlled by a pressure type flow controller for a small flow quantity, thus accurate flow rate control being achieved over the wide flow range.

[0025] In addition, it is so constituted that when a flow rate control by pressure type flow controllers allotted to all the flow rate ranges overlaps, the rising rate of control signals is restricted to make the flow rate  $Q$  of the gas to be supplied to a chamber continuously controlled.

[0026] With regard to a method for an internal pressure control of a chamber, an internal pressure of a chamber can be easily adjusted to and maintained at a specified set pressure due to the reason that a gas flow rate to be supplied to a chamber can be adjusted accurately and quickly. Accordingly, a conventional

[0027] automatic pressure controller APC can be eliminated, thus making it possible that facility costs for an exhaust system of a chamber are substantially reduced.

[0028] Furthermore, for a vacuum pump, an exhaust volume of the pump needs only to be big enough for the lowest pressure to a chamber previously set,

[0029] not requiring a vacuum pump to have a considerable margin for the exhaust volume as happened with a conventional exhaust system to a chamber. As a result, substantial reduction of the costs for an evacuation system can be achieved.

#### Brief Description of the Drawings

[0030] Figure 1 is a whole system diagram of the first embodiment of a gas supply facility to a chamber according to the present invention. The gas supply facility has been used for the basic experiment.

[0031] Figure 2 is a diagram to show relationships between an input setting (%) and a control signal (%) with a gas supply facility A in Figure 1.

[0032] Figure 3 is a diagram to show relationships between a flow rate setting (%), and a flow rate (%) of pressure type flow controllers and a supply flow rate  $Q$  to a chamber E with a gas supply facility A in Figure 1.



[0033] Figure 4 is a diagram to show relationships between an input state of control signals to pressure type flow controllers, and flow rate output Q1 and Q2 of the pressure type flow controllers and pressure P inside the chamber E with a gas supply facility A in Figure 1. (a) denotes the case when flow rates of two pressure type flow controllers are made to change from 0% to 100% in 60 seconds, (b) the case when flow rates are made to change from 0% to 100% in

[0034] 30 seconds, and (c) the case when flow rates are made to change from 0% to 100% in step-like.

[0035] Figure 5 is a diagram to show relationships between a flow rate setting (%) of a gas supply facility and a supply flow rate Q with regard to the second embodiment according to the present invention wherein three pressure type flow controllers are employed.

[0036] Figure 6 is a whole system diagram to show a state of implementation of a method for an internal pressure control for which a gas supply facility according to the present invention is employed.

[0037] Figure 7 is a diagram to show relationships between an internal pressure P which can be controlled with the method for an internal pressure control of a chamber and a supply flow rate Q illustrated in Figure 6.

[0038] Figure 8 is an explanatory drawing of a fluids supply facility wherein a conventional pressure type flow controller is employed.

[0039] Figure 9 is a block diagram of a pressure type flow controller.

[0040] Figure 10 is an explanatory drawing to show an exhaust system of a conventional process chamber.

#### List of Reference Characters and Numerals

- [0041] A Gas supply facility
- [0042] Gs Supply gas
- [0043] FCS(A) Pressure type flow controller for a small flow quantity
- [0044] FCS(B) Pressure type flow controller for a large flow quantity
- [0045] Q1 Control flow rate for a pressure type flow controller for a small flow quantity
- [0046] Q2 Control flow rate for a pressure type flow controller for a large
- [0047] flow quantity
- [0048] Q Supply flow rate to a chamber
- [0049] P Pressure inside a chamber
- [0050] E Process chamber
- [0051] APC Automatic pressure controller
- [0052] CV Conductance valve
- [0053] VP Vacuum pump
- [0054] V1-V3 Control valves
- [0055] L1 Gas supply pipe
- [0056] L2 - L3 Exhaust pipes
- [0057] Controller
- [0058] 1a Flow rate input setting part
- [0059] 1a' and 1a'' Control signal rising rate setting mechanisms
- [0060] 1b Signal conversion part
- [0061] 1c and 1d Control signals
- [0062] Best Mode to Carry Out the Invention: the following embodiments of the

present invention are described hereunde with reference to the drawings.

### The First Embodiment

[0063] Figure 1 shows the first embodiment of a gas supply facility to a chamber according to the present invention, which is a basic pattern of the said

[0064] gas supply facility.

[0065] With Figure 1, A designates a gas supply facility, Gs a supply gas, FCS(A) a pressure type flow controller for a small flow quantity, FCS(B) a pressure type flow controller for a large flow quantity, E a chamber, Q1 a control flow rate of a pressure type flow controller FCS(A) for a small flow quantity, Q2 a control flow rate of a pressure type flow controller FCS(B) for a large flow quantity, Q a supply flow rate to a chamber E, P pressure inside a chamber E, CV a conductance valve, VP a vacuum pump, V1-V3 control valves, L1 a gas supply pipe, L2 and L3 exhaust pipes, 1 a controller, 1a a flow rate input setting part, 1b a signal conversion part, and 1c and 1d control signals.

[0066] The aforementioned pressure type flow controllers FCS(A) and FCS(B) are basically identical to a conventional pressure type flow controller shown in Figure 1.

It is so constituted that a gas flow rate passing through an orifice is computed with a formula  $Q_c = K P_1$  (where K is a constant) by satisfying conditions that  $P_1/P_2$  or critical conditions of fluids between pressure  $P_1$  on the upstream side of an orifice and pressure  $P_2$  on the downstream side of an orifice are larger than approximately 2, and a control valve V provided on the upstream side is automatically controlled for opening and closing by the difference  $Q_y$  between the computed value  $Q_c$  and the set value  $Q_s$  to regulate pressure  $P_1$  so that the flow rate actually passed through an orifice is adjusted to the aforementioned set value  $Q_s$ .

[0067] With the embodiment, it is so constituted that an accurate flow rate control

can be continuously performed over the flow rate range from a minimum of 5SCCM to a maximum of 3100SCCM by using one with a rated flow rate of 100SCCM as a pressure type flow controller FCS(A) for a small flow quantity, and one with a rated flow rate of 3000SCCM as a pressure type flow controller FCS(B) for a large flow quantity.

[0068] The constitution of the aforementioned pressure type flow controllers FCS(A) and FCS(B) have been disclosed to the public. So, detailed explanations are omitted herewith.

[0069] The inside capacity of the aforementioned process chamber E is set at 1 l liters, and is continuously evacuated through evacuation lines L2 - L3 equipped with an automatic pressure controller APC and a conductance valve CV by means of a vacuum pump having an exhaust capacity of 300 liters/min, to maintain the inside of the chamber E in the vacuum of  $10^{-10}$  .

[0070] The aforementioned conductance valve CV is for regulating a pipe conductance for the evacuation system. A conductance valve CV has been disclosed to the public. So, detailed explanations are omitted herewith.

[0071] A stainless steel pipe with an external diameter of 6.35mm  $\phi$  and an internal diameter of 4.2mm  $\phi$  and a stainless steel pipe with an external diameter of 28mm  $\phi$  and an internal diameter of 24mm  $\phi$  are used for the aforementioned gas supply pipe L1 and exhaust pipes L2 and L3 respectively.

[0072] The aforementioned controller 1 comprises an input setting part 1a and a signal converter 1b, and a desired flow rate (%) to the rated maximum flow rate is set at the input setting part 1a.

[0073] Namely, a rising rate setting mechanism 1a' of a control signal 1c for a

pressure type flow controller FCS(A) for a small flow quantity and a rising rate setting mechanism 1a'' of a control signal 1d for a pressure type flow controller FCS(B) for a large flow quantity are provided with the said input setting part 1a. As stated later, the flow rate of process gas Gs required for a process chamber E is set with the input setting part 1a.

[0074] As stated later, to make both pressure type flow controllers FCS(A) and FCS(B) operated by setting a flow rate at any given rate from the minimum flow rate of 0% to the maximum flow rate of 100%, the aforementioned rising rate setting mechanisms 1a' and 1a'' of input signals for the input setting part 1a function to regulate the rising rates of control signals 1c and 1d applied to the pressure type flow controllers FCS(A) and FCS(B) for both small and large flow quantities.

[0075] For example, in the event that gas Gs while being supplied at the set flow rate of 50SCCM (an input set value of 1.613%) is increased to 2000SCCM (an input set value of 64.516%), the operation of a pressure type flow controller FCS(A) for a small flow quantity is switched to the operation of both pressure type flow controllers FCS(A) and FCS(B). It becomes necessary to make some lag time adjustment (approximately 30 seconds for a flow rate change of 0→100%) for a pressure type flow controller FCS(B) for a large flow quantity to reach 1900SCCM by regulating a rising rate of a control input signal 1d to FCS(B).

[0076] The aforementioned signal conversion part 1b is for outputting control signals 1c and 1d to both pressure type flow controllers FCS(A) and FCS(B) corresponding to the input setting (%) of the flow rates.

[0077] Control signals of a pressure type flow controller FCS(A) with the maximum flow rate of 100SCCM and a pressure type flow controller FCS(B) with the maximum

flow rate of 300SCCM are set for values of 0V (0SCCM) to 5V (100SCCM) and for values of 0V (0SCCM) to 5V (3000SCCM) respectively, and control signals 1c and 1d corresponding to allotted control flow rates are inputted to both pressure type flow controllers FCS(A) and FCS(B) from a signal conversion part 1b.

[0078] Figure 2 is a diagram to show relationships between a flow rate input setting (%), and control signals 1c and 1d at an input setting part 1a of the aforementioned controller 1. In Figure 2, a curve L shows a control signal 1c of a pressure type flow controller FCS(A) for a small flow quantity (100SCCM), and a curve H shows a control signal 1d of a pressure type flow controller FCS(B) for a large flow quantity (3000SCCM). For example, when a set flow rate is 50SCCM (a set flow rate  $\% = 50/3100 = 1.613\%$ ), only the FCS(A) is made operated, and a control signal  $1c = 5V \times 50/100 = 2.5V$  is inputted to the FCS(A).

[0079] Similarly, when a set flow rate is 2000SCCM (a set flow rate  $\% = 2000/3100 = 64.52\%$ ), the FCS(A) outputs a flow rate of 100SCCM with a flow rate setting  $\% = 100\%$ , and an control signal  $1c = 5V \times 100/100 = 5V$  is inputted to the FCS(A), while the FCS(B) outputs a flow rate of 1900SCCM, and a control signal  $1d = 5V \times 1900/3000 = 3.17V$  is inputted to the FCS(B).

[0080] Figure 3 is a diagram to show relationships between allotted control flow rates Q1 and Q2 of both pressure type flow controllers FCS(A) and FCS(B) and a total supply flow rate Q to a chamber E with a fluids supply facility A in Figure 1. A total flow rate Q is  $Q = 100/3 \cdot \text{set } \%$  (when only the FCS(A) is made operated, and Q is less than 100ACCM), or a total flow rate Q is  $Q = 3000/97 \cdot \text{set } \% + 700/97\text{SCCM}$  (when both the FCS(A) and the FCS(B) are made operated, and Q is more than 100SCCM).

[0081] Figure 4 (a)-(c) are experimental data to explain the needs for the

aforementioned control signal rising rate setting mechanisms 1a' and 1a'', and show relationships between a state of application of flow rate control signals 1c and 1d, and followability of a control flow rate Q to pressure P of a chamber in the event that both FCS(A) of 100SCCM and FCS(B) of 3000SCCM are made operated, and a total flow rate is increased from 0% (0SCCM) to 100% (3100SCCM). With the said experiment, a conductance valve CV of the exhaust system of a chamber is set to be in a state of full opening (a state wherein a vacuum pump VP is continuously under a full operation).

[0082] Namely, Figure 4 (a) shows a state of changes in pressure P of a chamber in the event that a setting signal to an input setting part 1a is made to change from 0% to 100% approximately in 60 seconds.

[0083] Figure 4 (b) shows a state of changes in pressure P of a chamber in the event that a setting signal to an input setting part 1a is made to change from 0% to 100% approximately in 30 seconds. Further, Figure 4 (c) shows a state of changes in pressure P of a chamber in the event that a setting signal to an input setting part 1a is made to change in step-like.

[0084] With Figure 4 (a) and Figure 4 (b), it is learned that so-called pressure control is perfectly achieved in a state wherein pressure P of a chamber continuously increases nearly proportional to the flow rate setting % (SET).

[0085] With Figure (c), however, it is found that pressure P of a chamber (a supply flow rate Q to a chamber E) is not able to change in step-like to step changes of a flow rate setting % (SET) (that is, step changes of a control signal 1c (or a flow rate Q1) and a control signal 1d (or a flow rate Q2)), thus making it impossible for a control of pressure P of a chamber for approximately 20 seconds to follow.

### The Second Embodiment

[0086] Figure 5 is a diagram to show relationships between a set flow rate and a flow rate output in the second embodiment for a fluids supply facility according to the present invention. With the said second embodiment, it is so constituted that these pressure type flow controllers FCS(A), FCS(B) and FCS(C) with the rated flow rates of 100SCCM, 3000SCCM and 5000SCCM respectively are employed, thus achieving accurate flow control over the wide flow rate range of 5SCCM-8100SCCM.

[0087] [0039] With Figure 5, flow rate characteristics of pressure type flow controllers FCS(A), FCS(B) and FCS(C) are shown by a curve L for 100SCCM, a curve H for 3000SCCM and a curve M for 5000SCCM respectively. Q is a supply flow rate to a chamber E.

[0088] That is, when a supply flow rate Q is less than 100-3100SCCM, a flow rate Q is determined by a formula:

$$[0089] \quad Q = (3100 - 10) / (40 - 1) \cdot (\text{SET}\% - 1) + 100$$

[0090] When a supply flow rate Q is 3100-8100SCCM, a flow rate Q is determined by a formula:

$$[0091] \quad Q = (5000 / 60) \cdot \text{SET}\% - (14000 / 60)$$

[0092] With the first embodiment in Figure 1 and the second embodiment in Figure 5, it is assumed that the one kind of supply gas was used. However, when more than two types of supply gas are used, the same number of gas supply facilities A shown in the first embodiment and the second embodiment as the number of different gas types can be provided in parallel, and gas supply facilities A are arbitrarily switched for operation, thus allowing a plurality of gases to be supplied to a chamber E.

[0093] Furthermore, with the first and second embodiments, a single type of supply



gas Gs is used. However, there is no need to say that a supply gas Gs can be a mixed gas, for example, mixture of Ar and CF<sub>4</sub> (with an arbitral mixing rate).

[0094] (A method for an internal pressure control of a chamber for which a gas supply facility is employed)

### The Third Embodiment

[0095] Figure 6 is a whole system diagram to show a method for an internal pressure control of a chamber for which a gas supply facility according to the present invention is employed.

[0096] Referring to Figure 6, a chamber E has an inside capacity of 11 liters, and its exhaust system comprises a conductance valve CV, a vacuum pump VP, an exhaust pipe L2 and an exhaust pipe L3. A vacuum pump has an exhaust volume of 300 liters/min.

[0097] The method for an internal pressure control of the said chamber is that an internal pressure inside a chamber E continuously exhausted by a vacuum pump having a certain exhaust capacity is regulated to a specified process pressure of approximately  $10^{-10}$  by finely adjusting the flow rate of fluids supplied therein.

[0098] Referring to Figure 6, firstly a conductance valve CV is fully opened to make a flow passage resistance to a minimum, and a vacuum pump VP is operated to evacuate a chamber to a degree of vacuum to meet the evacuation capacity of the vacuum pump VP.

[0099] Next, a flow rate Q of the supply gas to pressure P is determined by the pressure-flow rate characteristic curve of a chamber E and an evacuation system in Figure 7 determined beforehand.

[00100] Then, a gas supply facility A is operated to supply a flow rate Q of the gas Gs required to gain the aforementioned set pressure P into a chamber E.

[00101]           The range of an internal pressure adjustment inside the chamber E by the supply of the gas Gs can be changed by regulating the degree of opening of a conductance valve CV when the evacuation capacity of a vacuum pump is constant. As stated later, in the event that an internal pressure of a chamber is to be raised (a low degree of vacuum), the degree of opening of a conductance valve CV is made small to increase a flow passage resistance of the evacuation system, while in the event that an internal pressure of a chamber is to be lowered (a high degree of vacuum), a conductance valve CV is fully opened.

[00102]           Figure 7 is a diagram to show relationships between a supply flow rate Q to a chamber E in regard to the chamber E and the evacuation system, and the internal pressure P of the chamber. It shows the pressure-flow rate characteristics at the time when a vacuum pump is continuously operated at its rating and the degree of opening of a conductance valve CV is made either at its maximum or minimum.

[00103]           Namely, a curve A in Figure7 shows the pressure-flow rate characteristics when opening of a conductance valve CV is at the widest. A curve B shows the pressure –flow rate characteristics when opening of a conductance valve CV is at the narrowest.

[00104]           A curve C shows the pressure-flow rate characteristics at an arbitrary conductance of an evacuation system to realizes an arbitrary process point (1) or (2) inside the chamber E.

[00105]           As apparent in Figure 7, with a chamber E and an evacuation system in Figure6, a gas flow rate Q to the chamber E is regulated between 5-3100SCCM, and a conductance of the evacuation system is appropriately regulated, thus making it possible that pressure inside a chamber E over the flow rate/pressure range bordered

with numbers (1)–(4)–(5)–(3)–(2)–(7)–(6), in case of pressure,  $10^{-1}$ – $0.8 \times 10^{-1}$  Torr, can be regulated. Needless to say, by changing the constitution of an exhaust system (a conductance of an exhaust system, an evacuation capacity of a vacuum pump VP and the like) and a flow rate control range of a fluids supply facility A, the adjustment range of a flow rate/pressure (areas bordered by dotted lines) in the afore-shown Figure 7 can be changed. Therefore, it becomes possible that a flow rate range of a fluids supply facility A and an evacuation capacity of a vacuum pump VP are chosen appropriately depending on the conditions required for a process chamber E.

[00106] It is noted that, with semiconductor manufacturing facilities and the like, a pressure control range is normally set at  $10^{-1}$ – $10^{-1}$  Torr, and a flow rate control range Q at 3SCCM–5000SCCM.

[00107] Inactive gases such as He, Ar and the like or gases mixed therewith are used for gases Gs to be supplied into a chamber E for an pressure adjustment.

[00108] Furthermore, there is no need to say that a process gas itself or a mixed gas can be used for the gas Gs supplied into the aforementioned chamber E.

#### Feasibility of Industrial Use

[00109] The present invention is adaptable for use of a control of gases supplied to a process chamber in a semiconductor manufacturing facility, a control of internal pressure inside a process chamber and the like.

## Claims

1. A gas supply facility for a chamber, comprising:
  - a plurality of pressure type flow controllers connected in parallel;
  - a controller to control the operation of an aforementioned plurality of pressure type flow controllers; and
  - a chamber exhausted by a vacuum pump, wherein
    - the pressure type flow rate controller comprises an orifice, a pressure detector provided on an upstream side of the orifice, a control valve provided on an upstream side of the pressure detector, and a computation control part
    - whereby a gas flow rate  $Q_c$  passing through the orifice is computed with pressure  $P_1$  detected by the pressure detector using a formula  $Q_c = KP_1$  (where  $K$  is constant), and a difference  $Q_y$  with the set flow rate  $Q_s$  is output to a control valve as a driving signal, thereby maintaining the ratio  $P_1/P_2$ , of a pressure  $P_1$  on the upstream side of the orifice and a pressure  $P_2$  on the downstream side, as approximately two or more, and also allows accurate flow control over a wide flow rate range by making one of the pressure type flow controllers to be a controller to control the gas flow rate range up to 10% of the maximum flow rate to be supplied to a chamber, while the remaining pressure type flow controller(s) comprise controller(s) to control the rest of the gas flow rate range.
2. A gas supply facility to a chamber as claimed in Claim 1, wherein at least two said pressure type flow controllers are connected in parallel, and one is made to be a controller for a small flow quantity range, while the other is made to be a pressure type flow controller for a large flow quantity range.

3. A gas supply facility to a chamber as claimed in Claim 1, wherein at least two said pressure type flow controllers are connected in parallel, and a flow rate range of one said pressure type flow controller, for a small flow quantity, is made to be 0.1-10% of the maximum flow rate, while a flow rate range of another said pressure type flow controller, for a large flow quantity, is made to be 10-100% of the maximum flow rate.
4. A gas supply facility to a chamber as claimed in Claim 1, wherein said plurality of pressure type flow controller is operated, starting with a pressure type flow controller for a smaller flow quantity range to one for a larger flow quantity, in turn, by means of control signals remitted from a signal conversion part in the controller.
5. A gas supply facility to a chamber as claimed in Claim 1, further comprising a rising rate setting mechanism of control signals to be remitted to said pressure type flow controllers allotted for all the flow rate ranges of the flow controllers, and said pressure type flow controllers supply the set flow rate of gas after a specified lapse of time following the remittance of the aforementioned control signals.

6. A method for internal pressure control of a chamber, comprising the steps of:
  - continuously operating a vacuum pump to decompress, through an exhaust line equipped with a conductance valve, a chamber supplied with a gas from a gas supply facility equipped with a pressure type flow controller;
  - determining relationships between a gas supply flow rate and an internal pressure of the chamber at both the maximum degree and minimum degree of opening of the aforementioned conductance valve, respectively, to ascertain a control range for the gas supply flow rate to the chamber and a control range of the internal pressure of the chamber; and
  - regulating the gas flow rate, while supplying gas from the gas supply facility, to the gas supply flow rate corresponding to the internal pressure of the chamber to be set, determined from the relationship between the gas supply flow rate and the internal pressure of the chamber, to maintain the chamber at the desired set pressure.
7. A method for an internal pressure control of a chamber, comprising the steps of:
  - supplying a chamber connected to both a gas supply facility and an exhaust system having a conductance valve; and
  - maintaining an internal pressure of the chamber at a set pressure by regulating both an opening of the conductance valve of the exhaust system and a supply flow rate of the gas supply facility.
8. A method for an internal pressure control of a chamber as claimed in Claim 6, wherein said gas supply facility comprises:
  - a plurality of pressure type flow controllers connected in parallel;
  - a controller to control the operation of the plurality of pressure type flow

controllers; and wherein

the pressure type flow controller comprises an orifice, a pressure detector provided on an upstream side of the orifice, a control valve provided on an upstream side of the pressure detector, and a computation control part whereby a gas flow rate  $Q_c$  passing through the orifice is computed with pressure  $P_1$  detected by the pressure detector using a formula  $Q_c = KP_1$  (where  $K$  is a constant) and a difference  $Q_y$  with the set flow rate  $Q_s$  is outputted to a control valve as a driving signal, thereby maintaining the ratio  $P_1/P_2$ , of a pressure  $P_1$  on the upstream side of the orifice and a pressure  $P_2$  on the downstream side, as approximately two or more, and also allows accurate flow control over a wide flow rate range by making one of the pressure type flow controllers to be a controller to control the gas flow rate range up to 10% of the maximum flow rate to be supplied to a chamber, while the remaining pressure type flow controller(s) comprise controller(s) to control the rest of the gas flow rate range; and wherein

the controller comprises an input setting part to set a gas flow rate to be supplied to a chamber and a signal conversion part to convert an input value to the said input setting part into control signals to pressure type flow controllers, thus making it possible to accurately control flow rate control over a wide flow rate range by remitting control signals from a signal conversion part to all the pressure type flow controllers.

### Abstract of the Invention

The present invention makes it possible to prevent substantial reduction of flow rate control accuracy in a small flow quantity range, to achieve an accurate flow rate control over the entire range of a flow rate control, and also to allow control of a wide pressure range of a chamber with an accurate flow rate control.

Namely, with a gas supply facility having a plurality of pressure type flow controllers connected in parallel and a controller to control operation of pressure type flow controllers to supply a desired gas exhausted by a vacuum pump to a chamber while controlling its flow rate, one pressure type flow controller is made to be a controller to control a gas flow rate range up to 10% of the maximum flow rate to be supplied to a chamber, while the remaining pressure type flow controllers are made to be ones to control the rest of the gas flow rate range.



FIG. 1

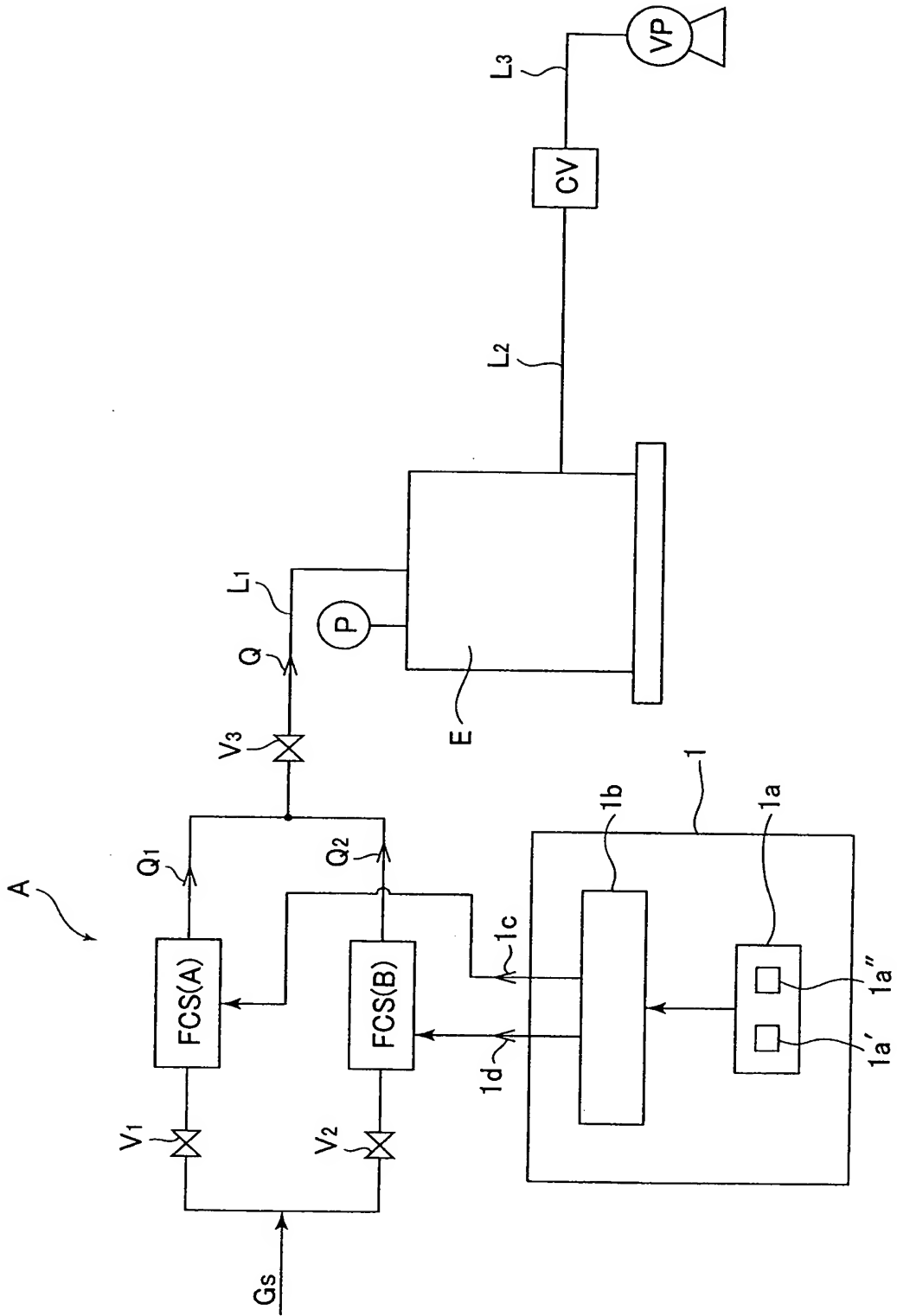


FIG. 2

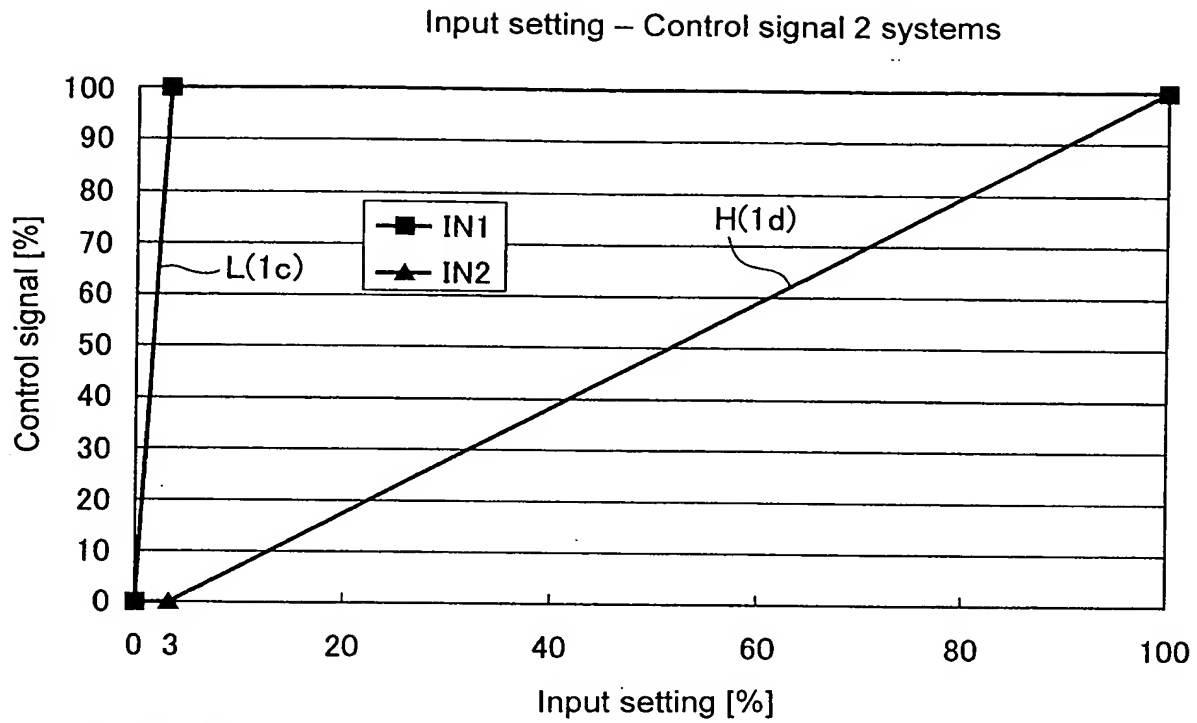


FIG. 3

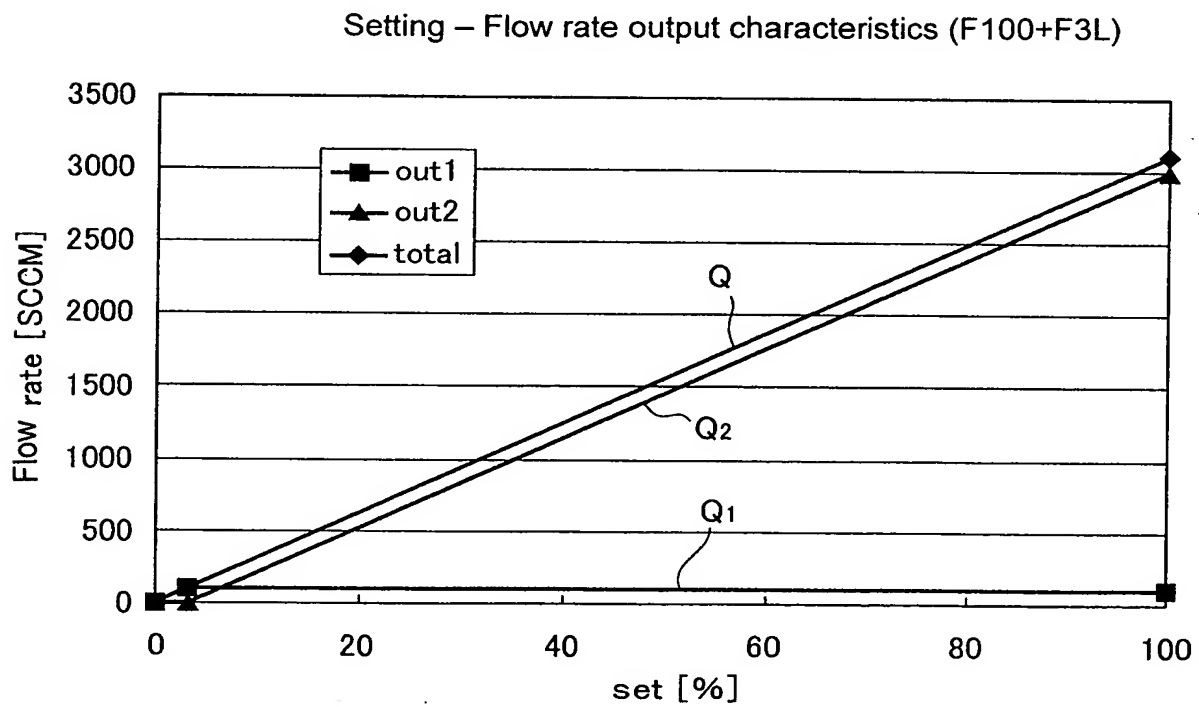


FIG. 4

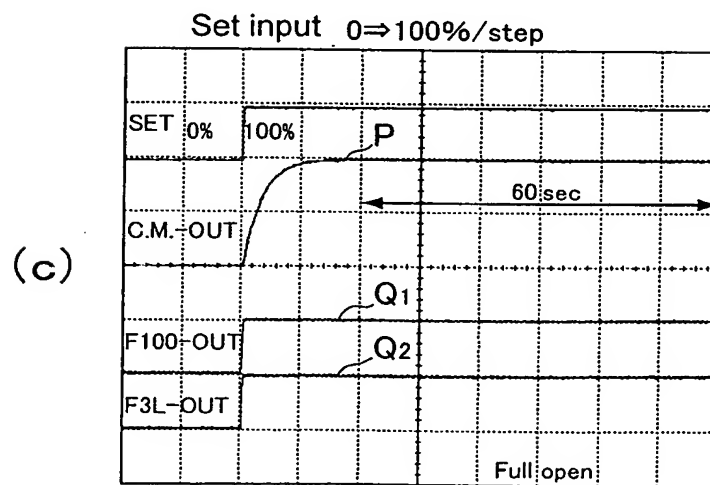
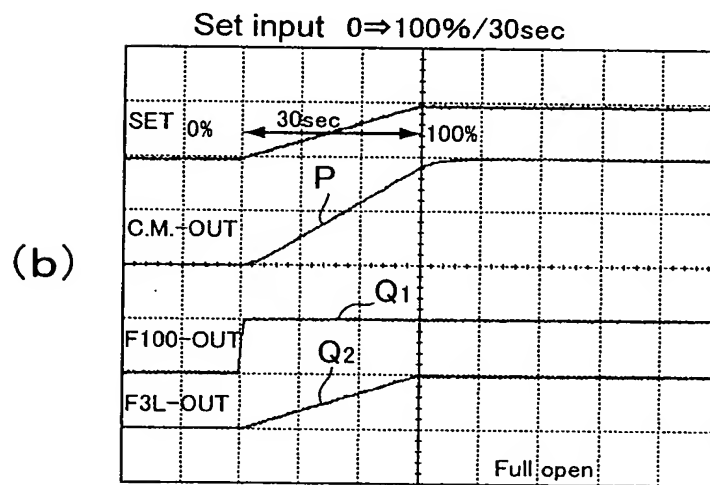
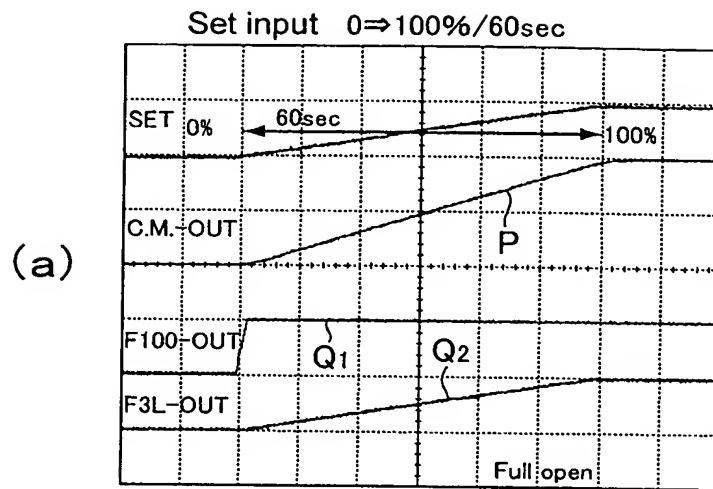


FIG. 5

Setting – Flow rate output characteristics (F100+F3L+F5L)

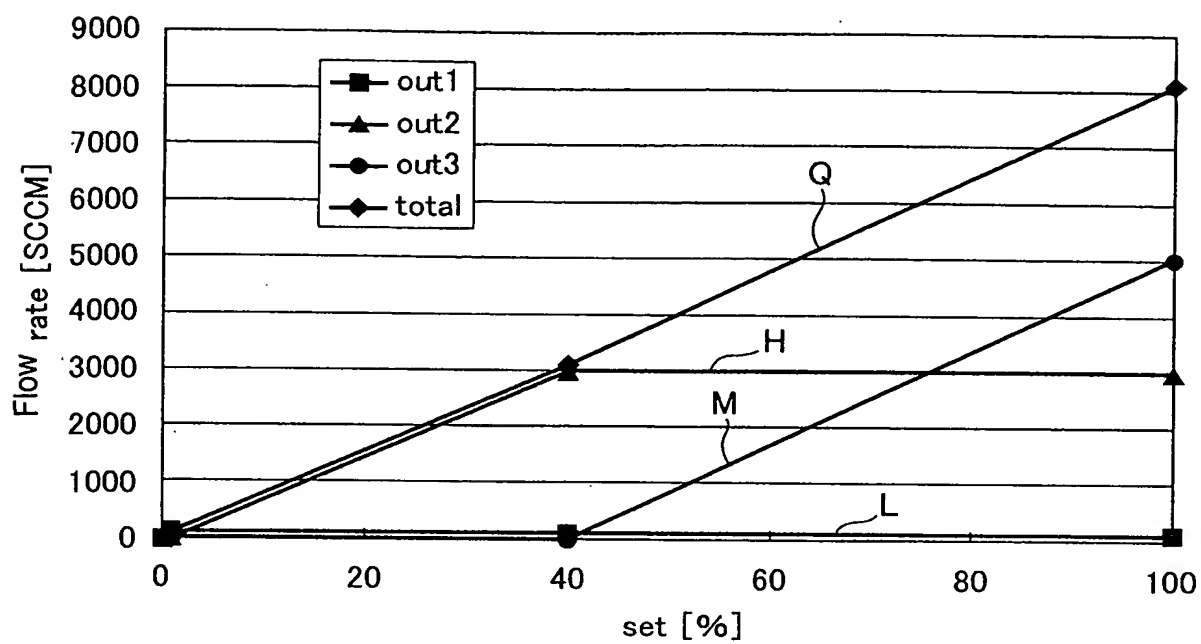


FIG. 6

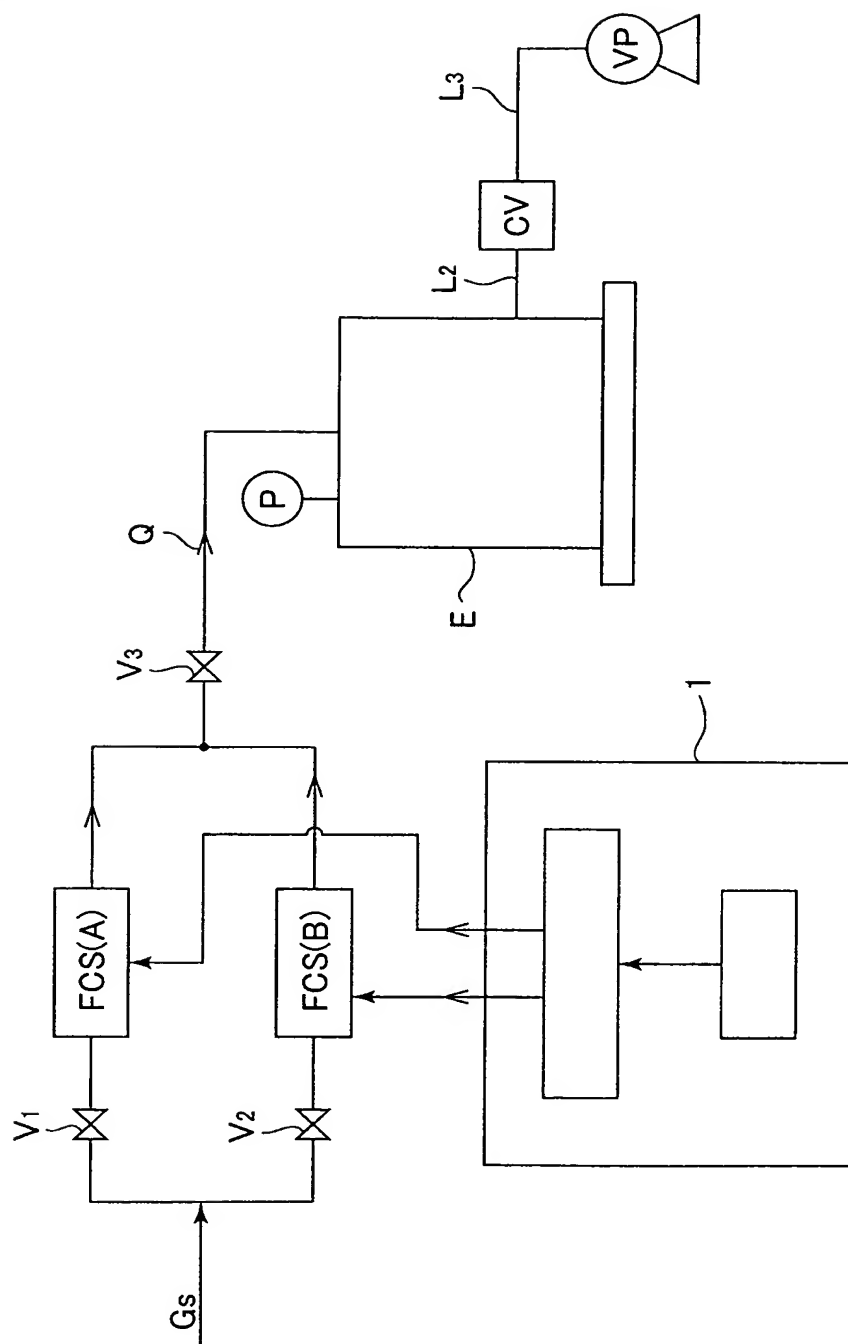


FIG. 7

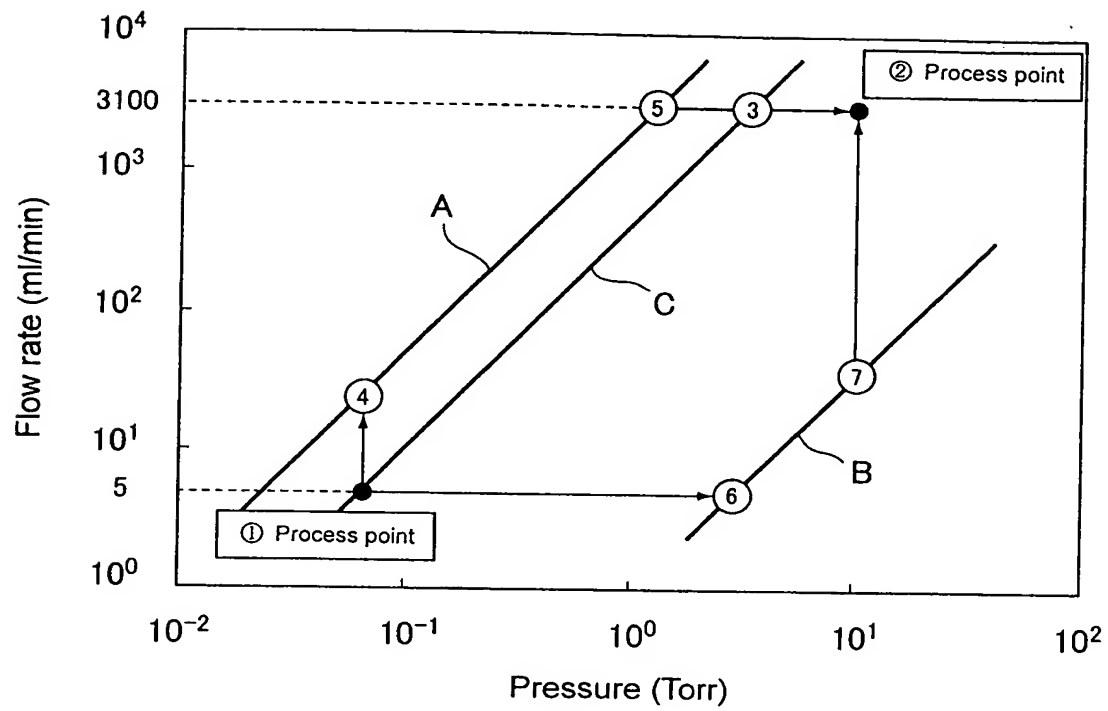


FIG. 8

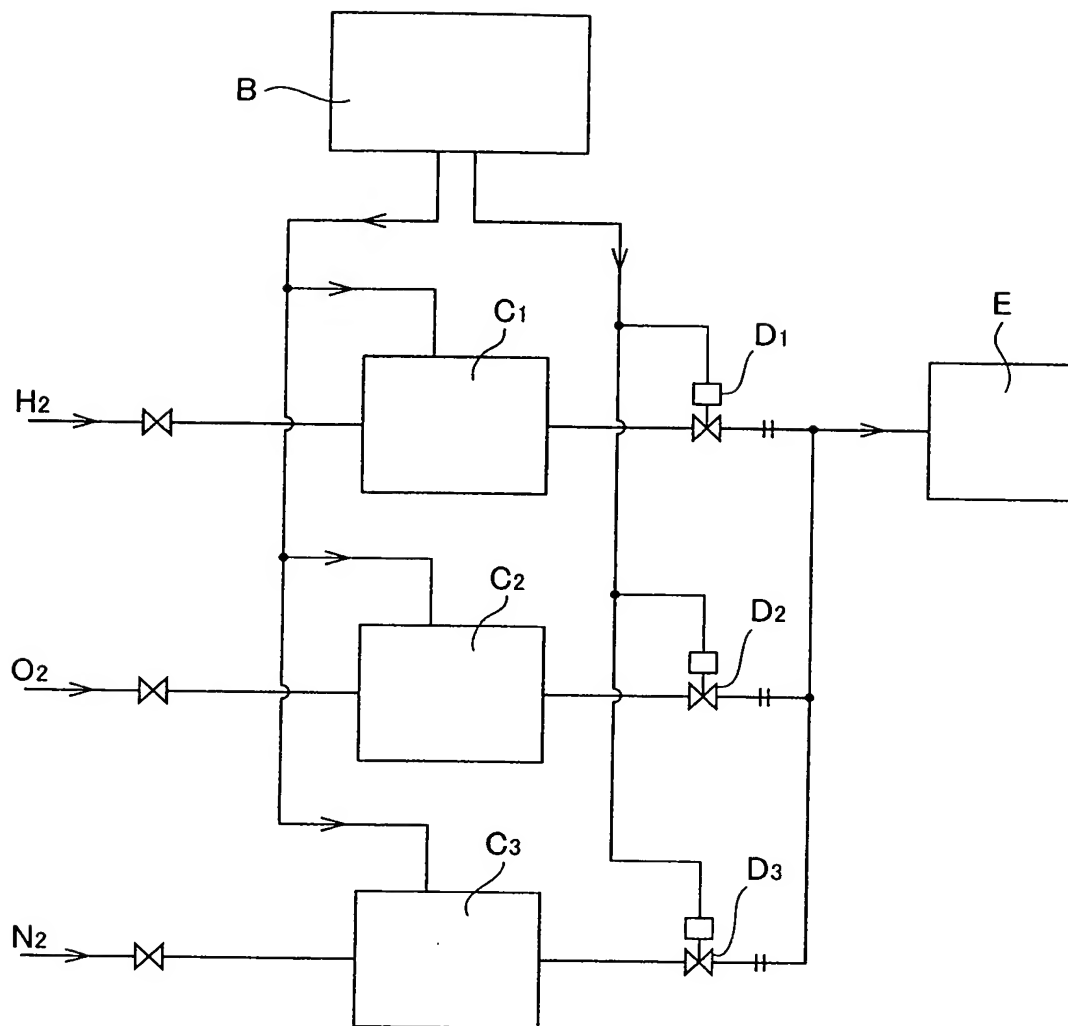


FIG. 9

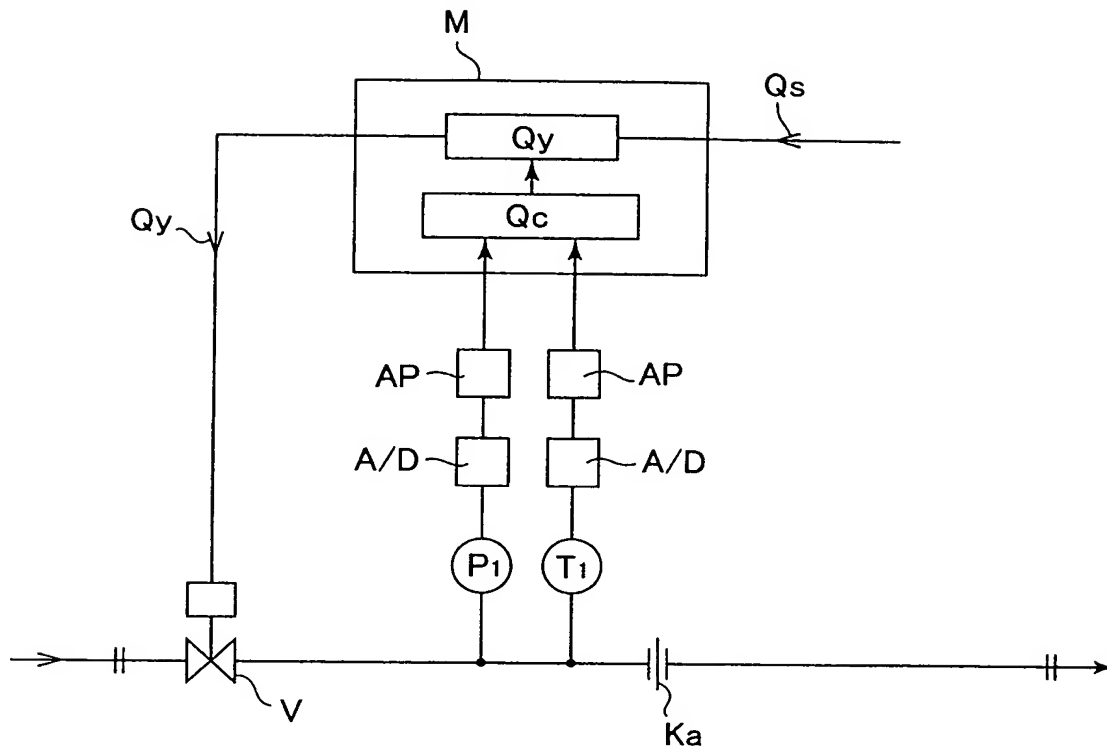




FIG. 10

